Feasibility of Using an Adjustable Sit-Stand Workstation at Work and its Impact on Non-Exercise Activity in Sedentary Office Workers: A Pilot Randomized Crossover Trial

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Abstract

Background: Over the last century, physical activity has been systematically removed from our daily lives through automation, a trend that continues today, and this has led to Americans spending a majority of the waking hours in a sedentary state (very low energy expenditure state, such as sitting). This phenomenon is thought to have detrimental health effects such as excess weight gain, cardiovascular disease, and premature mortality. A new field has emerged that has started to focus on reducing inactive time during the waking hours by building in more light activity, known as non-exercise activity, throughout the day.

Purpose: The purpose of this study was to determine whether a non-exercise activity could be increased during workday by installing a sit-stand desk at work. Method: A randomized cross-over study was conducted in a Minneapolis office with 28 sedentary office workers who participated in a four week intervention period (used a sit-stand desk to replace 50% of sitting time at work with standing) and a control period (usual sitting work environment), in random order, with a two week wash-out period (usual sitting, no measurement) in between. The intervention involved the installation of sit-stand work desks at each worker's desk and ergonomic instruction for its use (*Ergotron*, Inc., St. Paul, MN).

Results: Sedentary, computer-based, office workers replaced about 50% of their sitting time with standing (p-value <.0001). This intervention significantly increased activity during work hours (p-value <.0001). It appears that the intervention resulted in about 35 minutes of sedentary time being replaced with non-sedentary time on a workday. Moreover, this intervention significantly decreased caloric intake (211 kilocalorie/day, p-value = 0.01), despite the fact that instruction was given to maintain the same life-style during both periods of the study. Furthermore, this intervention significantly increased relaxation, calmness, energy, overall sense of well-being and decreased fatigue. The intervention turned out to be highly popular with over 96% of the subjects enjoying the use of the sit-stand work station and 89% choosing to have a sit-

stand desk permanently installed at their work at the end of the study with the goal of standing a large portion of their workday.

Discussion: Overall, a sit-stand desk appears to be a promising tool to reduce sedentary time at work. Given the proportion of waking hours spent at work, sit-stand desks may mitigate the health burden associated with sedentary lifestyles.

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Chapter 1 Introduction

1.1 Background

Two out of every three U.S. adults are overweight and one out of every three Americans is obese (1). One of the main culprits for the obesity epidemic is the modern lifestyle with ever increasing automation that has substantially decreased energy expenditure (2). Meanwhile, energy intake has shifted in a positive direction (3). Therefore, we have systematically created a state of constant excess energy storage that predictably results in excess weight gain.

Eating a healthy diet and performing regular exercise have been the traditional advice for maintaining a healthy weight. The American College of Sports Medicine's (ACSM) guideline for physical activity is to get a minimum of 2.5 hours per week of moderate intensity aerobic exercise (e.g. brisk walk, 3-6 metabolic equivalent of task (MET)) or 1 hour per week of vigorous intensity aerobic exercise (e.g. jog, 6-10 MET) and two days a week of muscle strengthening training of unspecified duration (e.g. weight-lifting) (4). If each muscle strengthening session lasts about 30 minutes, then one who meets the guideline spends approximately 3.5 hours per week doing purposeful exercise. The aerobic exercise requirement is met by 46% of Americans, muscle strengthening guideline is met by 23% of Americans, and only 19.4% meet both (5). Therefore, in reality, most of us spend much less than 3.5 hours per week in purposeful exercise.

Given that the average person sleeps approximately 8.5 hours/day, there are about 15.5 waking hours per day and 108.5 total waking hours per week (6). This leaves, even for a person who is meeting the ACSM guideline, about 105 hours a week when one is not purposefully exercising or sleeping. The activity during this time is called non-exercise activity (1-3 MET) – which accounts for spontaneous activities like standing, fidgeting, and walking– and may be a critical component of body weight regulation and chronic disease risk.(7) People who spend most of those 105 hours per week in prolonged sedentary behavior, which includes activities with very low energy expenditure (≤1

MET) like sitting, are more likely to have risk factors (waist circumference, HDL-cholesterol, C-reactive protein, triglycerides, insulin, pancreatic beta-cell function and insulin sensitivity) for metabolic diseases and are more likely to face adverse health outcomes such as premature mortality from cardiovascular disease or premature all-cause mortality (8) (9)(10). In fact, meeting the ACSM exercise guidelines does not seem to be sufficient for chronic disease prevention (11) (12). Breaks in sedentary behavior have been shown to have beneficial health effects in cardio-metabolic risk factors (waist circumference, C-reactive protein, postprandial glucose and insulin levels) (13) (8)(14)(15). Previous research suggests that obese people tend to sit 2.5 hours more than their lean-counter parts; therefore, strategies to increase non-exercise energy expenditure by 2.5 hours per day may be an important component of interventions to treat and prevent obesity (16).

Given that working adults in developed countries spend about half of their working day sitting, the workplace is an appropriate site for interventions aimed at reducing sedentary time (17,18). Therefore, an intervention designed to modify the workplace environment from one that encourages sedentary behavior to one that encourages standing and more movement may be effective in preventing adverse health outcomes associated with prolonged sitting. Few experimental studies have been completed on this relatively novel idea (19). To our knowledge, no such experimental studies have taken place in the office-based adult population. There is therefore an urgent need to fill this evidence gap (20).

1.2 Objective

This goal of the study was to determine the feasibility of using an adjustable sit-stand desk in the workplace and its effect on non-exercise activity in sedentary office based workers. Energy and relaxation level, and dietary intake were also examined in line with the following hypotheses.

1.3 Hypotheses

Due to the novel nature of the study, the goals were to establish preliminary estimates of potential effect size. Following were the hypotheses to that end.

1. It is feasible to install an adjustable sit-stand desk in sedentary office based workers and ask them to use it without disrupting their work.
2. Amount of non-exercise activity (i.e. time spent walking and other light activity) will be higher during the standing intervention period compared to the control period (usual sitting).
3. Self-reported energy and relaxation levels will be higher for the standing intervention period compared to control.
4. Self-reported energy intake (i.e. total kilocalories consumed) and composition (i.e. protein, carbohydrate, fat) will not differ between the standing intervention periods and control. This is a null hypothesis because no data was available to make a prediction in either direction due to the novel nature of the study.

Chapter 2 Methods

2.1 Experimental Design

This was an un-blinded, controlled, randomized cross-over pilot study of office workers at a company located in the Twin Cities Metro Area, Minnesota, United States (*Caldrea*, Inc.). The cross-over design included a 4-week standing intervention (adjustable sit-or-stand desks were installed and subjects were asked to gradually replace 50% of their sitting time with standing, at their own pace) and a 4-week control period (sitting at work as usual), separated by a 2-week washout/usual habits period (sit-or-stand desk was uninstalled and subjects returned to usual sitting). For period 1, subjects were randomly assigned to either the standing intervention or the control in a 1:1 ratio. No interim analyses for efficacy or fidelity were done.

2.2 Participants

Eligible participants were adults (aged 18 and over) employees of the company who are sedentary during the majority of the workday and used a single computer workstation for at least 20 hours per week. Subjects had to be willing to stand for 50% of the workday and partake in sub-maximal aerobic fitness tests. Subjects who could potentially be harmed from this intervention, such as those with significant musculoskeletal problems, autoimmune conditions, or varicose veins were excluded. Pregnant women were also excluded.

2.3 Settings

The experiment took place at the *Caldrea*, Inc. headquarters in Minneapolis, MN from January to April 2012. The office consisted of one large floor of a larger office building with about 50 employees, all working in close proximity to one another in short-walled cubicles. During the first phase of the study, during the months of January and February, the *Caldrea* Company was located on the 4th floor of the building while their new space on the 5th floor was being furnished. During the wash-out phase of the study in February and March of 2012, they moved to the 5th floor. The second phase of the study took place in the 5th floor during March and April 2012. In the 4th floor (appendix Figure 7-1), employees were situated closer together than they were in the 5th floor (appendix Figure 7-2) where the layout was more spread out.

2.4 Recruitment

The study was approved by the University of Minnesota Institutional Review Board. A recruitment presentation was made at an all-employee meeting in early January 2012 and it was followed a few days later with enrollment interviews in a private room at the worksite which entailed a review of all of the inclusion/exclusion criteria. Demographic information (age, ethnicity, education, and job-title), work schedule, and past year physical activity level was collected at enrollment. Pertinent health history of the subjects was also discussed at enrollment; the study physician (Steven Stovitz, M.D.) was consulted to clear enrollment in the study. During the recruitment presentations and during the informed consent process it was made clear that participating in the study did not change the subjects' relationship with the employer or the research institution in any way. Coworkers and supervisors were expressly requested to neither support nor oppose the study in order to prevent undue influence about participation. The voluntary nature of the study was stressed.

2.5 Intervention, Control, and Wash-Out Periods

Based on randomization, either the first or third month involved an active intervention to use an adjustable sit-or-stand desk with the goal of gradually decreasing sitting time over the month to approximately four hours per day, or half of the workday. The desks were provided and installed by *Ergotron*, Inc. (Eagan, Minnesota, USA) and three different models of desks were used to best match the need of the participant: Workfit-S®, a setup that attaches to the front of one's existing desk that can hold computer monitor, keyboard, and mouse (Figure 2-1); Workfit-A®, a setup that is identical to Workfit-S but attaches to the back of one's existing desk (Figure 2-2); Workfit-D®, a whole desk that is easily moved up and down (Figure 2-3). The Workfit-

A and S also came with an added work-surface and all three types of desks came with anti-fatigue mats for comfort during standing.

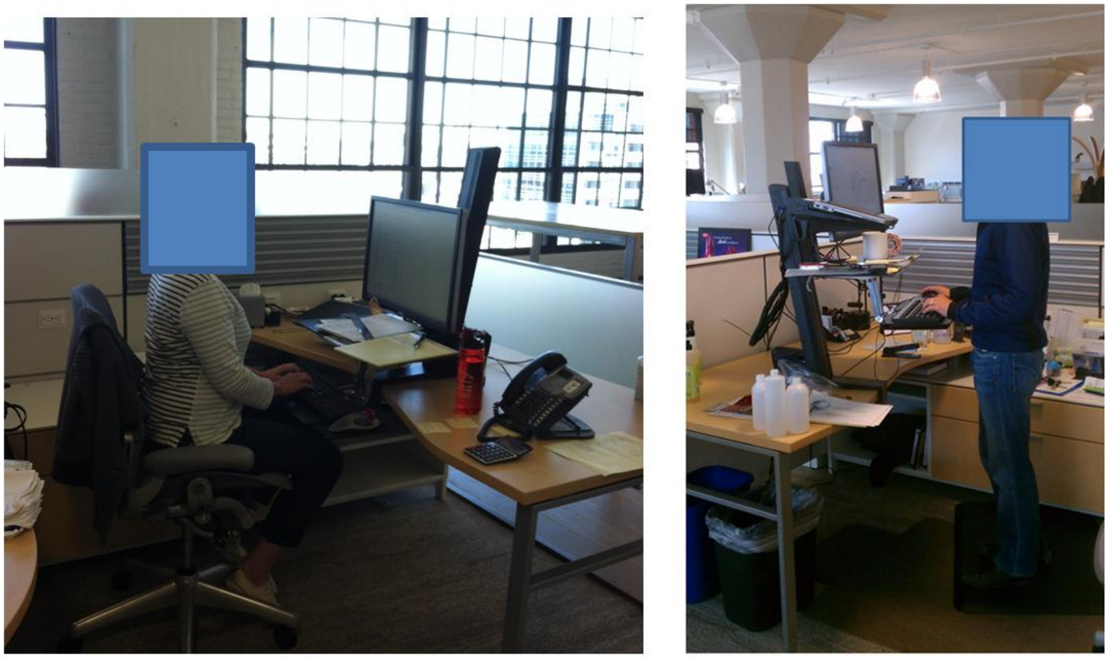

Figure 2-1. A participant is standing via the Workfit-S, which attaches to the front of the existing desk. An extra work-surface can be used for office accessories, and an anti-fatigue mat is positioned underfoot.

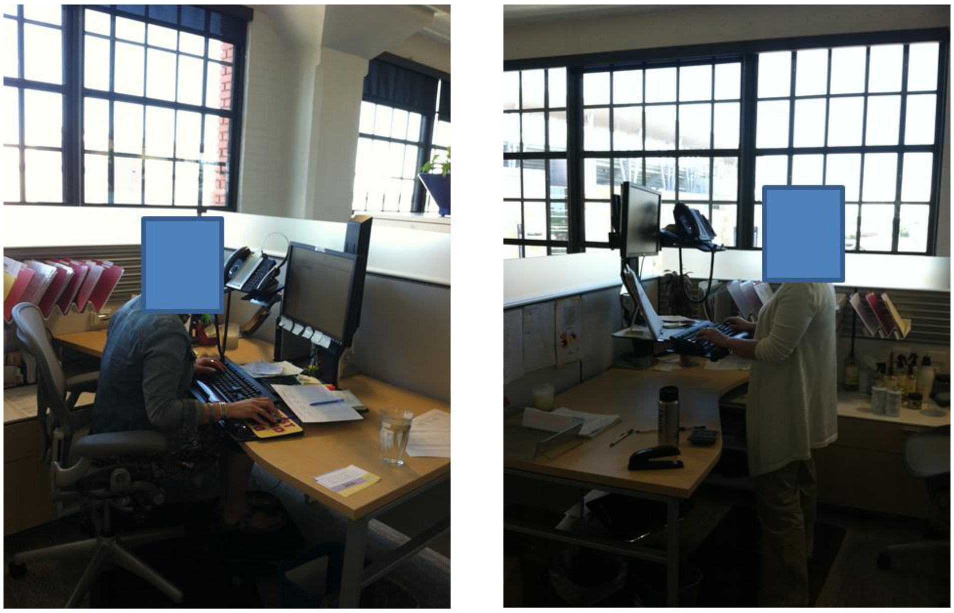

Figure 2-2 A Workfit-A is shown, which is similar to the Workfit-S, but attaches from the back of the existing desk, thus allowing more of the existing desk space to be used.

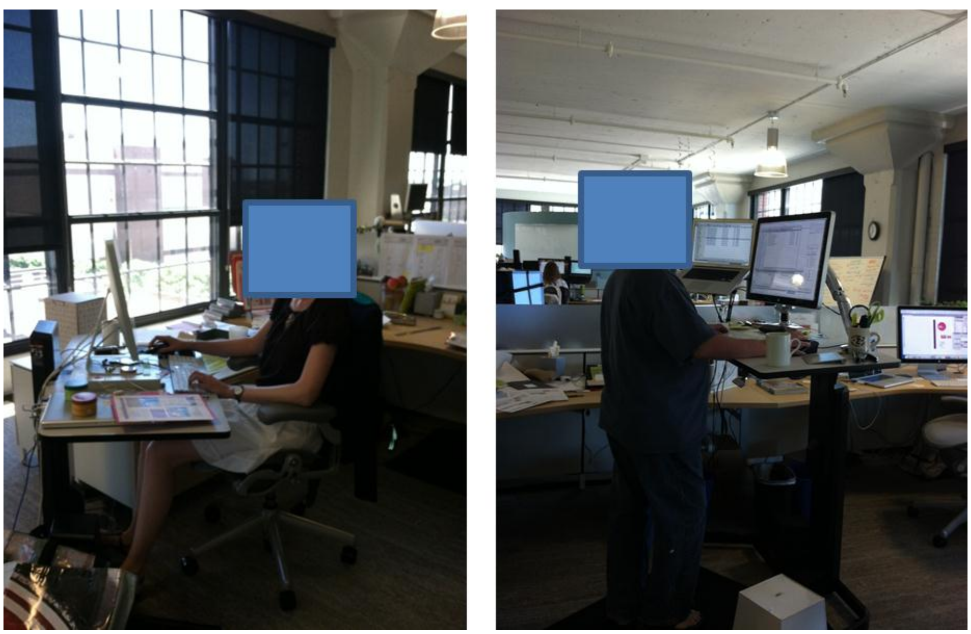

Figure 2-3 The Workfit-D is shown. This is a stand-alone desk, replacing the existing desk and providing an ample work surface.

An ergonomics specialist from *Ergotron* Inc. ensured proper standing and sitting height for the monitor, keyboard, mouse, and chair to prevent musculoskeletal discomfort among participants. After the initial explanation of the expectation to gradually decrease sitting time by 50% an email was sent at the beginning of the first week reminding subjects of that goal. At the beginning of second week, subjects were asked to decrease sitting time more, via email. At the beginning of the third week, subjects were asked to reach the 50% standing time goal if possible and at the beginning of the fourth week, subjects were asked to continue efforts to reach this goal, both times via email. No other communication was made to subjects about sitting or standing.

During the control period (about 4 weeks long) the subjects were asked to maintain their usual work habits before the study started. An ergonomics evaluation was given at the beginning on the control period as well to ensure correct height for the monitor, keyboard, mouse, and chair.

In order to measure adherence to the study protocol, sitting and standing time was measured subjectively using the occupational sitting and physical activity questionnaire (OSPAQ) This questionnaires have been shown to have acceptable validity (sitting = 0.65; standing = 0.49; walking = 0.27-0.29) and reliability (0.73-0.90) as compared to accelerometer (21,22). The survey was loaded onto a study specific survey website hosted by *SurveyMonkey.com* (USA). Link to the survey was emailed at the end of each week during the intervention and control period to determine sitting and standing time during the previous week.

The washout period, which was approximately two weeks long, involved reverting to their usual sitting behavior prior to the study. It was essentially identical to the control period except no measurement or contact was made with the subjects during these two weeks.

2.6 Outcomes

Several outcomes of interests were assessed in this study, as shown in Table 2-1.

Table 2-1 Outcomes and Measurement Technique

Outcome	**Measurement Technique**	**Frequency**
Feasibility	Take-up Rate	End of the Study
Total Activity	*Gruve* accelerometer	All Waking Hours
Diet	Automated Self-Administered 24-Hour Recall	Once a Week
Energy/fatigue; Relaxation/Calmness; Hunger; Overall Wellness	Ecological Momentary Assessment	Twice Daily, during Workday

The primary end-point with respect to feasibility was the proportion of participants who chose to have a sit-or-stand desk installed in their workspace at the end of the study. The rationale behind this was that given that the sit-stand desk severely compromises existing work-surface, only someone who plans on using the sit-stand desk regularly would want one.

The primary end point with respect to effectiveness of the intervention was the amount of non-exercise activity (i.e. time spent walking and other light activity) during the two periods. Subjects were asked to wear a tri-axial accelerometer (*Gruve* ®, *Muve* Inc. Minneapolis, MN) around the waist (as shown in Figure 2-4) during all waking hours during each period. The *Gruve* accelerometer has been validated to measure the whole spectrum of activity (sedentary, light, moderate, and intense) with the exception of water activity (not water-proof) and weight-lifting activity (cannot measure movements isolated to a body part) (validation study is in press, (23,24)). Sedentary activity is defined as 0 to 1 MET, light is defined as 1 to 3 MET, moderate is defined as 3 to 6 MET, and intense is defined is 6+ MET. Lying, sitting, and static standing, where one stands still without any movement is likely to be considered *sedentary* because the accelerometer was placed on the hip. Standing while swaying hips and leisure walks (speed <3 mph) are likely to be considered *light*. Brisk walking and similar activities are likely to be considered *moderate,* and anything more vigorous, such as jogging, is considered *intense*.

Figure 2-4 The *Gruve* accelerometer worn on a subject's hip.

Self-reported energy and relaxation levels were measured through twice-daily ecological momentary assessment (EMA) questions (~1 minute in duration for completion time), which was loaded onto the study specific survey website and the link to the survey was emailed at two random times during the workday, usually once in the morning and once in the afternoon. The EMA was sent twice daily, at random times, usually morning and afternoon, to collect a large number of observations at various times throughout the workday throughout both periods. EMAs have been used effectively to capture mood of participants at that particular moment in time because they don't rely on memory and are simple and quick; moreover, because of many repeated samples, they seem to be a valid and reliable measure of the outcome of interest (25). The EMA questionnaire is provided in the appendix (Figure 7-3).

Self-reported energy intake and dietary composition was also assessed as a secondary outcome. It was measured using a web-based version of a 24 hour dietary recall hosted free of charge by the National Cancer Institute for use by researchers, called the "Automated Self-Administered 24-Hour Recall" (ASA-24). The access to the survey website was sent on a randomly selected day each week and respondents were asked to complete the survey as soon as possible (20-30 minutes in duration), which prevented them from changing their diet in anticipation of the survey.   Multiple 24 hour diet recalls are deemed to be the best methodology for subjective dietary assessment because it uses a multiple-pass method (quick list, review quick list, add details, and review), which has been validated to accurately estimate mean total energy and protein intakes, and studies have shown it to be more valid than food frequency questionnaire or food diaries (26)(27).

2.7 Data-Collection, Data-Storage, and Privacy-Protection

All subject data were collected in privacy, using a private room at the worksite or the metabolic van parked outside the worksite, and data were saved using a password protected computer, on a password-protected server located at the University of Minnesota, and using a virtual private network which is also password protected. All data used to identify subjects were separated from the main study database to protect the confidentiality/privacy of the subjects. The main study database with all of the variables from the collected data included a unique identifier specific to each subject so that only the investigators were able to discriminate among subjects for appropriate analysis. This unique identifier had no meaning whatsoever to the identity of the subjects.

2.8 Compensation

Subjects were compensated up to $150 for completion of the whole study, which was prorated as follows: $20 for the baseline measurements, $30 for completing the first study month, $30 for the baseline measurements at the start of the second study period following the washout period, and finally $70 for completing the whole study. Participants were also given the option of keeping their sit-stand desk at the end of the study.

2.9 Sample Size

Given that this was a novel pilot study, no sample size calculation was performed because no study of this type had been done in sedentary office workers. In order to determine feasibility of this intervention, the researchers primarily focused on finding an agreeable worksite and accepted the fact that the sample size would be determined based on the worksite. Also, funding and time constrains limited the researchers from pursuing multiple worksites or longer intervention. Therefore, many of the secondary outcomes, and perhaps even the primary outcome, could be under-powered, especially given the short duration of the study.

2.10 Randomization

Upon enrollment, each subject was given a unique computer generated identification number (randomizer.org). That identification number was used by a member of the research team who was not part of the enrollment or data collection process to assign a random order using Microsoft Excel 2007 (Microsoft Inc., Washington) to each subject, which determined if the subject was assigned the intervention during period 1 or 2, using a 1:1 allocation in 1 block of 35. It was not possible to conceal allocation or blind subjects or researchers given that the sit-stand desk had to be installed at the workstation of subjects and all employees worked on one floor with low cubicles.

2.11 Analysis

Mixed-model repeated measures linear regression was used to analyze continuous outcomes data with SAS (‘*Proc Mixed’, SAS* 9.2, Cary, North Carolina). Microsoft Excel was used for various data collection, management, and simple statistical procedures such as descriptive statistics, as well as some hypothesis testing, such as chi-square tests, with discrete outcomes (*Microsoft* Inc., Bellevue, WA). A type I error of $\alpha < 0.05$ was accepted as statistically significant.

Chapter 3 Results

3.1 Participant Flow

Thirty five participants were assessed for eligibility, six did not meet inclusion criteria, 29 were randomized, 17 were allocated to receive the intervention during period 1 and the other 12 were to receive the intervention during period 2, as shown in Figure 3-1. In the period 2 intervention group, one participant missed most of the control period due to illness and therefore was excluded from the rest of the study. In the period 1 intervention group, one participant found different employment two weeks before the end of the study. This person was retained in the intent-to-treat (ITT) analysis. The ITT analysis was performed on 28 subjects.

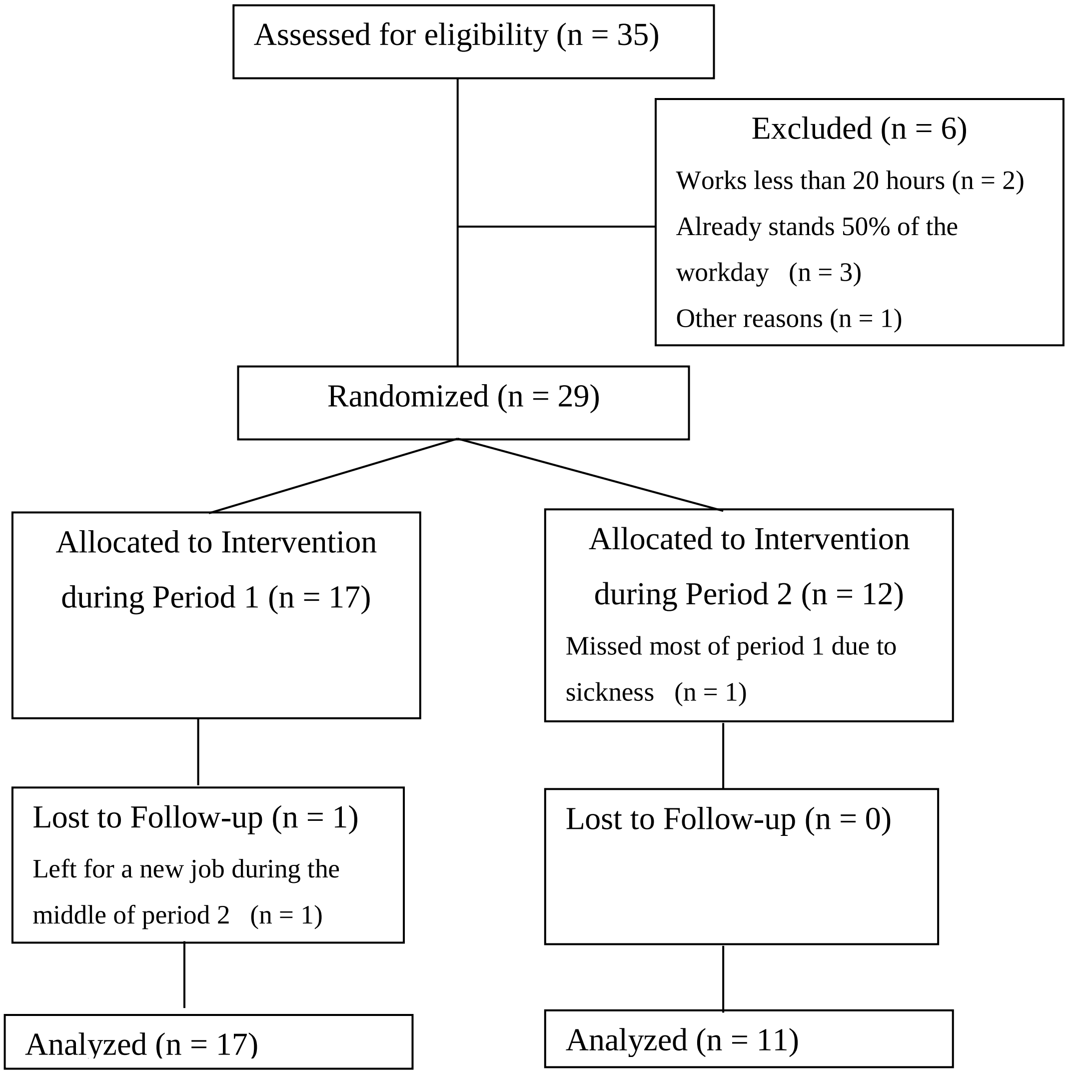

Figure 3-1 Participant Flow

3.2 Baseline Data

The two groups had similar baseline characteristics in terms of age, sex, BMI, and hours spent at work, as shown in Table 3-1.

Table 3-1 Baseline Demographic and Clinical Characteristics

	Period 1 Intervention (period 2 control) (N = 17) Mean (standard deviation)	Period 2 Intervention (period 1 control) (N = 11) Mean (standard deviation)
Age (Years)	40.1 (8.8)	42.0 (8.3)
Sex (Male)	4 (24%) [N (%)]	5 (45%) [N (%)]
Body Mass Index (Kg/m^2)	25.9 (5.27)	25.1 (3.89)
Hours Spent at Work	35 (7)	37 (5)

3.3 Evaluation of the Standing Intervention

The OSPAQ was used to measure whether subjects stood more during the intervention period compared to the control period; results are shown in Figure 3-2 . Subjects sat for about 79% of their time, stood for about 10% of the time, walked for about 10% of the time, did heavy work for about 1% of the time during the control period. During the intervention period, subjects sat for about 39% of the time, stood for about 49% of the time, walked for about 10% of the time, and did heavy work for about 1% of the time. The two distributions were significantly different, according to a chi-square test (p-value < 0.0001). There was a 50% decrease in sitting time and a 500% increase in standing time between control and intervention period, suggesting that the intervention was actually applied and the subjects were adherent to the study protocol.

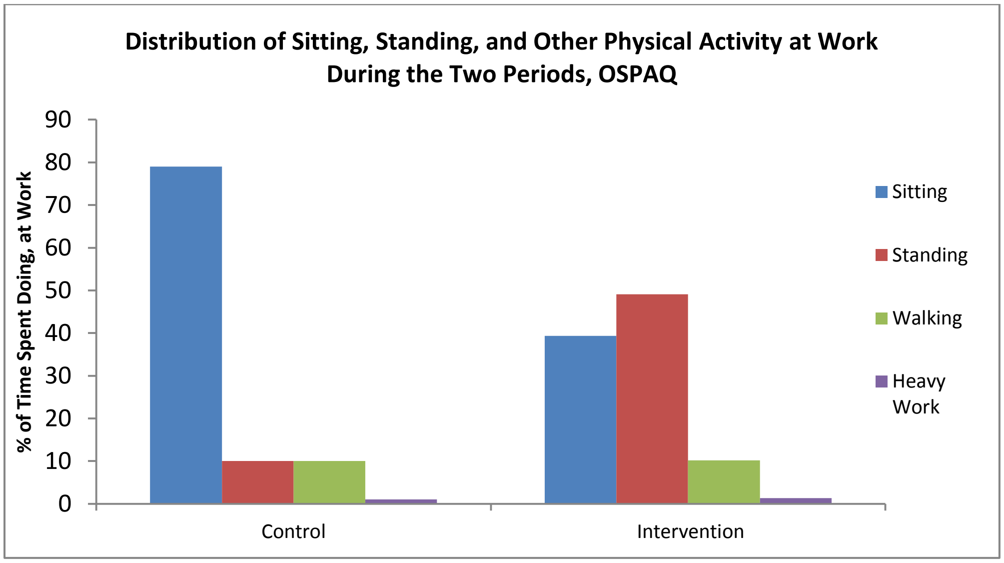

Figure 3-2 Occupational Sitting and Physical Activity Questionnaire Results

3.4 Feasibility

The experiment had a very positive reception at the workplace which as assessed by the one-on-one interviews and focus group sessions, which will be fully analyzed and reported in the near future. By and large, subjects enjoyed the flexibility to be able to sit or stand while working. Lack of workspace was the biggest complaint with the Workfit-A or Workfit-S; subjects who had the Workfit-D did not report this problem. For this study, feasibility was going to be quantitatively determined by the number of people who chose to have a sit-stand desk installed at the end of the study with enthusiasm to use it regularly; results are shown in Table 3-2. To that end, 88.9% of the subjects wanted to keep using the sit-stand desk at the end of the study. Out of the 11.1% who did not, 66.6% would have liked to stand for a portion of their workday if they could get a different desk (Workfit-D instead of Workfit-S or A) because they required more work surface.

Table 3-2 Experience with Standing at Work and Take-up of Sit-Stand Desks at the End of the Study

	Number	Percent
Total	28	100%
Lost to follow-up	1	3.57%
Total excluding Lost to Follow-up	27	100%
Liked Standing at Work	26	96.3% (93% ITT)
Did not like standing at work	1	3.70%
Wanted *Ergotron* Sit-Stand desk at the end of the study	24	88.9% (86% ITT)
Did not want desk at the end of the study	3	11.1%
Would have Stood if they could get a different desk	2 out of those 3	66.6%

3.5 Non Exercise Activity

Subjects were asked to wear the *Gruve* accelerometer for all waking hours during each period. Every week subjects also answered a survey about their work schedule for that week, time spent at *Caldrea*, time spent for work but offsite, vacation/sickness/holiday, which allowed us to separate work time and non-work time. Work time was defined as Monday through Friday 8 am to 5pm and the rest was defined as non-work time. The *Gruve* output gave an estimate of kilocalories (kcal) expended per hour. All hours with less than 1 kcal per hour were excluded because it was thought that the *Gruve* device was probably not on the subject during those hours. Also, only days with at least 8 consecutive hours were accepted into data analysis, which was 50% of the total hours subjects were asked to wear the device per day (during all waking hours, which is approximately 16 hours). 'Island hours', hours of activity which were not preceded or followed by another hour of recorded activity were excluded because it was not possible to determine of the portion of that hour when the subject was wearing the device. Hourly activity for each period for each person was averaged. The outcomes were adjusted for order and period effect.

Data were analyzed in accelerometer units per hour (AU/hr), which is the raw data from the accelerometer based on movement (Figure 3-3). Total AU/hr was not statistically different between control and intervention period. AU/hr during work hours was significantly higher during the intervention period compared to the control period ($p < .0001$). AU/hr for non-work hours were lower during the intervention period compared to control, but this difference was not statistically significant ($p = 0.12$).

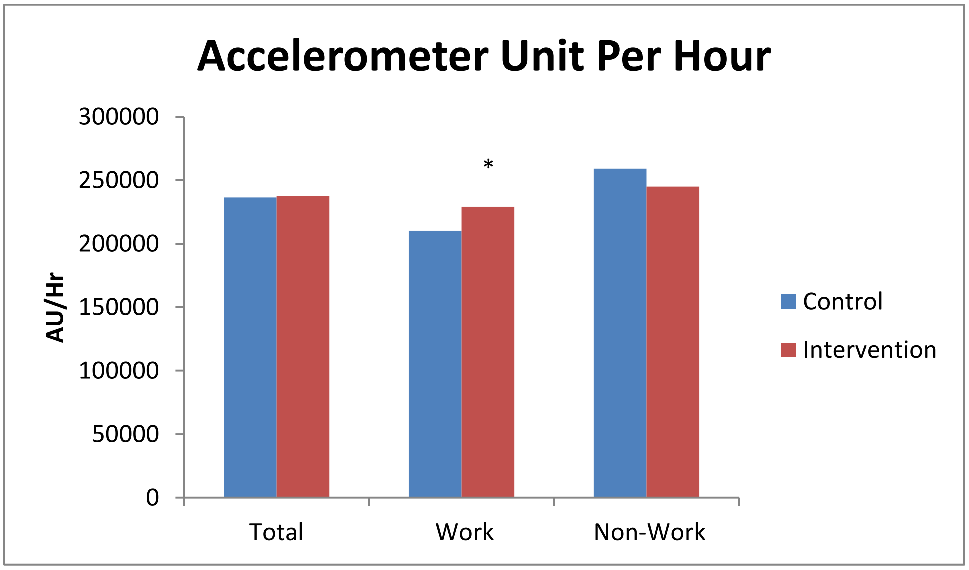

Figure 3-3 Total activity, activity during work, and activity outside of work (* denotes statistically significant difference during work hours)**.**

The AU/hr was converted to the four aspects of activity: sedentary, light, moderate, and intense, using proprietary algorithms by *Gruve*, Inc. Total activity, work-hour activity, and non-work activity was further analyzed in terms of sedentary time per hour. Sedentary time per hour is a continuous variable; therefore, it was analyzed using repeated measures linear regression (*SAS* “Proc Mixed”), results are shown in Figure 3-4.

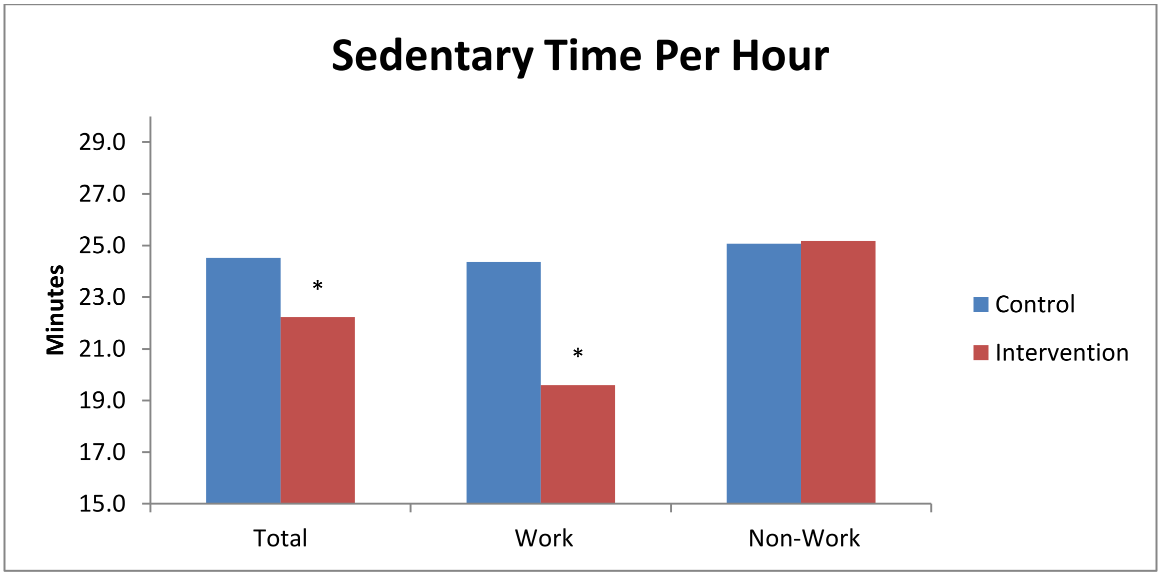

Figure 3-4 Sedentary time during the two periods (* denotes statistically significant difference)**.**

Total activity results demonstrate that during the control period subjects spent about 24.5 minutes out of an hour in a sedentary state, while during the intervention period they spent about 22.2 min in a sedentary state, a difference of 2.3 (95% CI = 1.78 to 2.86) minutes per hour, as shown in Figure 3-4. This amounts to, over 16 waking hours in a day, about 37 minutes of sedentary time being replaced with non-sedentary time.

Activity results during work hours demonstrate that during the control period subjects spent about 24.4 minutes out of an hour in a sedentary state, while during the intervention period they spent about 19.6 min in sedentary state, a difference of 4.8 (95% CI 4.14 to 5.39) minutes per hour, as shown in Figure 3-4. This amounts to, over an 8 hour workday, about 38 minutes of sedentary time being replaced with non-sedentary time. Therefore, almost all the difference in sedentary time during the whole day can be attributed to work hours.

Activity results during non-work hours demonstrate that during the control period subjects spent about 25.1 minutes out of an hour in a sedentary state, while during the intervention period they spent about 25.2 min in sedentary state, a difference of -0.1 (95% CI -0.99 to 0.79), minutes per hour, as shown in Figure 3-4. Therefore, non-work hours had almost no effect on the total change in sedentary time.

3.6 Ecological Momentary Assessment

The EMA included questions about relaxation, calmness, energy, fatigue, sluggishness, hunger and overall well-being, on a scale of 1 to 5 where 1 indicated ‘not at all’ and 5 indicated ‘extremely’ (see Figure 7-3 for a copy of the scale). Prior to the analysis, all the variables were transformed so that the higher score was more favorable (e.g., 5 for ‘tired’ was recast to mean ’not at all’). All responses by each person for each question were averaged for each period and were compared; results are shown in Table 3-3. Outcomes were adjusted for period effect; no order effect was observed therefore it was not included in the regression analysis. Subjects were significantly more relaxed, calmer, more energetic, less tired, less sluggish, and felt a higher overall sense of well-being during the intervention period. Subjects also reported feeling less hungry, although it didn't quite reach statistical significance ($p = 0.06$). Subjects were also asked if they were standing or sitting while answering the survey, which served as an indicator of intervention adherence (standing = 1, sitting = 0). During the intervention period subjects reported standing 70% of the time, while during the control period subjects reported standing about 2% of the time.

Table 3-3 Ecological Momentary Assessment Data Analysis

	Control Period (scale of 1 to 5)	Intervention Period (scale of 1 to 5)	Treatment effect (P-value)
Relaxed	3.4	3.5	0.02
Calm	3.4	3.5	0.004
Energetic	3.2	3.3	0.03
Not Tired	3.6	3.7	0.05
Not Hungry	3.7	3.9	0.06
Not Sluggish	3.9	4.0	0.01
Overall Wellness	3.4	3.5	0.008
Standing (0= sit, 1 = stand)	0.02	0.70	<0.0001

3.7 Dietary Intake

Dietary intake was measured by the ASA24, which was completed on-line by subjects once a week on a random day of the week that was unannounced until the day of assessment. Subjects with at least one dietary assessment from each period were used for analysis. There were 150 total acceptable observations and 26 people filled out at least 1 survey in each period where they ate a usual amount of food.

Results are shown in Table 3-4. In terms of total caloric intake, subjects reported consuming an average of 2037 kcal per day during the control period and an average of 1826 kcal during the intervention period, with a mean difference of 212 kcal (p-value = 0.01). In terms of grams of total protein consumption, subjects consumed an average of 79 grams of protein during the control period and an average of 70 grams of protein in the intervention period, a mean difference of 9 grams (p-value = 0.04). Total fat intake during the control period was averaged 80g and during the intervention period averaged 72 g, a mean difference of about 9 gram(p-value = 0.07). Average total carbohydrate consumption during the control period was 234 g and during intervention period was 217g, a mean difference of 17 g(p-value = 0.13). There was no period and order effect.

Table 3-4 24 Hour Dietary Recall Results from the Two Periods

	Control Period	Intervention Period	Control - Intervention (estimate, 95% CI)	P-Value
Total Kilocalories	2037	1825	211.8 (44.7 to 379.0)	0.01
Protein (g)	78.6	69.6	9.0 (0.55 to 17.48)	0.04
Total Fat (g)	80.5	71.7	8.79 (-0.62 to 18.21)	0.07
Total Carbohydrate (g)	234.3	217.1	17.15 (-5.06 to 39.37)	0.13

Chapter 4 Discussion

Sedentary office workers were asked to reduce their sitting time during work by 50% with the use of adjustable sit-stand workstations. A cross-over design was used where each subject served as his or her own control; subjects were randomized to a month of either the sit-stand intervention or usual sitting control during month one, followed by a two week wash-out, and followed by a month of whichever the subject didn't do in the first month. In this paper, results in regards to adherence to standing intervention, feasibility, non-exercise activity, mood, and dietary intake were reported based on *a priori* hypotheses.

4.1 Adherence to the Standing Intervention

In this study, standing and sitting time were measured subjectively with the OSPAQ. According to the OSPAQ, during the intervention period subjects replaced about 50% of their sitting time with standing time, compared to the control period and increased their standing time by 500%. This demonstrates that, on average, the subjects were relatively adherent towards the goal of replacing 50% of the sitting time with standing.

4.2 Feasibility

It was hypothesized that it is feasible to install an adjustable sit-stand desk in sedentary office-based workers and ask them to use it without disrupting their work. At the end of the study, out the 27 subjects who could be contacted, 96% reported liking the ability to sit or stand during work. This overwhelmingly positive response was expressed in one-on-one interviews and focus group sessions, which will be formally reported at a later time. 89% wanted to have an *Ergotron* desk installed at their work-space. Three of the 27 subjects opted to not have the desks installed and 2 of them decided so because they did not like the *Ergotron* product due to the lack of desktop space. They would have wanted a standing desk if they could have a Workfit-D, the sit-stand workstation with a larger work surface. Therefore, a sit-stand desk that allows sedentary office workers the option to work while sitting or standing is suitable for the work performed and is well received by them.

4.3 Non-exercise Activity

It was hypothesized that the amount of non-exercise activity (i.e. time spent walking and other light activity) would be higher during the standing intervention period compared to the control period (usual sitting). No difference was found in total activity, as measured by accelerometer unit per hour; however, activity during work hours was significantly higher during the intervention period. This suggests that a sit-stand desk is effective at increasing activity during work. Activity during non-work hours appeared to be less during the intervention period compared to control, although this finding was not statistically significant and needs further attention in future studies. It is possible that people may compensate for higher amount of activity during work hours by being less active during non-work hours.

However, when the raw accelerometer units were converted into sedentary and non-sedentary time, it was found that total sedentary time was reduced by about 2 minutes per hour and replaced with non-sedentary time, which amounts to a 37 minute of sedentary time being replaced with non-sedentary time in a day. For work hours, during the intervention period, subjects replaced about 5 minutes of sedentary time per hour, about 38 minutes of sedentary time during an 8 hour workday. This suggests that almost all of the difference in sedentary time during the whole day was due to the intervention. Sedentary time during the non-work hours was essentially unchanged in the two periods.

These results are similar to what was found in the few previous studies that have been done. One prospective experimental study done in first grade classrooms comparing sit-stand desk versus tradition sit-only desk found significantly higher caloric expenditure in the treatment group (19). One recent study focused on reducing sitting time among office workers found that a barrage of activity promoting behaviors during work and non-work hours resulted in about a 48 minute decrease in sitting time during waking hours (28). Another study showed that taking breaks from sedentary behavior such as taking even a 1 minute walking break every hour resulted in significantly higher caloric expenditure (29).

The findings from the present study suggest that replacing over 30 minutes of sedentary time during the workday can be done simply by providing sedentary workers with a sit-stand desk and asking them to attempt to work 50% of the time by standing via weekly email reminders. A workplace wellness program focused on reducing sedentary time can use this knowledge to build in the component of non-exercise activity as part of its overall effort to improve employee health.

Sit-stand desks used for this study are in the $400 to $1000 range (Workfit A or S are priced around $400 and Workfit-D is priced around $900, with bulk discounts often applied on these prices), which is in the price range for typical high quality office chairs and desks. Therefore this may be an affordable option for many employers or employees, especially if the desks result in a healthier and happier workforce in the long run. *Caldrea* management did not reduce the workload of the employees who participated in the study. From conversations with employees, one-on-one interviews, and focus group sessions, it was apparent that productivity of the employees was not hampered (data not shown).

4.4 Ecological Momentary Assessment

It was hypothesized that self-reported energy and relaxation levels will be higher for the standing intervention period compared to control. Subjects were significantly more relaxed and calm, more energetic and less tired/sluggish, and felt a higher overall sense of well-being during the intervention period, compared to control. Although the effect size was small, one would only expect a subtle effect on the mood of a person during work due to the implementation of a standing desk. Feeling more energetic and less tired is a bit counter-intuitive since standing may be more physical demanding than sitting, but on the other hand standing recruits more muscle fibers and stimulates blood flow, which may help with alertness and maintaining energy levels and concentration on certain work tasks and office interactions. However, these results may merely reflect the novelty of the intervention and may thus be the result of a Hawthorne effect or social desirability bias. However, the use of the EMA protocol, being unannounced, randomly allocated, and not subject to recall errors and related biases, would suggest that the findings may be real. Therefore, a wellness intervention such as reducing sedentary time by standing, may not only be beneficial on the physiological level, but also may positively impact the psychological states and overall wellbeing of sedentary office workers.

4.5 Dietary Intake

It was hypothesized that self-reported energy intake (i.e. total kcal consumed) and composition (i.e. protein, carbohydrate, fat) would not differ between the standing intervention periods and control. However, we observed that total caloric intake and protein intake was significantly lower during the intervention period. Total fat and carbohydrate intake also appeared to be lower during the intervention period but not quite statistically significantly. This finding seems counter-intuitive because during the intervention effect of about 30 minutes of sedentary time was replaced by non-sedentary time, implying an increase in caloric expenditure, and one might expect that subjects would eat more to main energy balance. An alternative explanation may be that subjects reacted to the intervention by being more health conscious, and thus ate less frequently or consumed smaller portions. It could also be true that reducing sedentary time and increasing non-exercise activity actually makes people less hungry or buffers the desire to spontaneously eat during the workday. The hunger EMA suggests that people felt less hungry during the intervention period, compared to control ($p = 0.06$); which may explain why people reported consuming less calories during the intervention period. There was no period or order effect for hunger.

One should also interpret the dietary intake results with cautions, as diet is notoriously difficult to measure and often fraught with non-differential as well as systematic biases, even when assessed by the best subjective method, the unannounced multiple 24-hr recall method used in the present study. Despite these short-comings, the results suggest the possibility that an office-based standing intervention may be an excellent way to maintain or achieve a healthy weight because it decreases sedentary time, increases non-exercise activity, and decreases energy intake.

4.6 Limitations

This study has several limitations. First of all, the intervention could not be blind to the subjects or the investigators due to the nature of the intervention; this potentially biasing some of the results, specifically the self-reported outcomes, away from the null. The order in which the intervention was administered may impact the outcome; this is known as the "order effect", but this is minimized by randomizing the order, which was done in our study. Moreover, the order was adjusted for as a covariate in the regression analysis. Similarly, there may have been a period effect simply because people behave differently during different months of the year; this was especially relevant in this study because during period 1 the subjects were on the fourth floor of the same building and during period 2 the subjects were working on the fifth floor following an office move that occurred during the washout period. Nonetheless, as with the order effect, the period effect was included as a covariate in our regression models. Another limitation is the chance of "carry-over" of benefits or harms from one treatment into the next since one individual goes through both intervention and control. This bias can be minimized with an adequate "wash-out" period, as well as by randomly assigning the order of treatment vs. control, as was done in this study. In this study, a two week washout period was used, which may or may not be long enough for a four week intervention; however, this would bias the results towards the null. Another limitation of the study may be the "learning" or "training" effect. Subjects were expected to slowly work up to their optimal standing time, however, given that the intervention was only for four weeks, some subjects did not achieve the goal; thus the treatment effect may have been attenuated. On the other hand, subjects during the control period may have learned to stand or walk more from their experience in the intervention period (if that was done in period 1) or from watching their coworkers; this would also likely attenuate the magnitude of the effect size towards the null. Lastly, this study was done in a company that makes environmentally friendly cleaning products, and the culture of the company is that of a good steward of the planet as well as that of its employees. There was high enthusiasm for this study among the employees and among the management; in fact all high level managers participated in the study. This enthusiasm may not be found if this study is replicated in more general populations with less passion for healthy living.

In any case, the cross-over design is a very strong experimental approach for the hypotheses tested because the same individual is serving as his/her control, minimizing the need for concern for between-person differences and variations. Moreover, this study was done in the 'real-world', at the worksite; therefore, the natural workflow of the employees did not appear to be disrupted to a significant or negative extent. Along with high internal validity, the study appears to have potential for good external validity, or generizability to similar office-based sedentary workers. Therefore, despite the known limitations, this pilot study is among the first to explore the short-term (four weeks) effects of increased standing time in the workplace on a variety of physiological, psychological, and behavioral responses. The results should be valuable to the field and these preliminary findings should inform future efforts to conduct larger and longer randomized trials.

Chapter 5 Conclusion

Much of the world is suffering from an obesity epidemic. Obesity is associated with many chronic diseases and is consuming hundreds of billions of dollars per year in healthcare cost and billions more in costs unaccounted for. The traditional approach for combatting the problem of excess weight gain has been eating a healthy diet and exercising daily. However, a new field has emerged that is focusing on reducing inactive time during the day by building in more light activity, known as non-exercise activity, throughout the day. In this study, we have shown that a desk that allows one to work while sitting or standing can be implemented in the workplace for sedentary, computer-based, office workers to replace sitting time with standing. This intervention significantly increased activity during work-hours and may replace about 35 minutes of sedentary time with non-sedentary time during a workday. Moreover, this intervention seems to significantly decrease caloric intake, despite the fact that instructions were given to maintain the same life-style during both periods of the study. Furthermore, this intervention seems to improve relaxation/calmness, increase energy, decrease fatigue, and increase the overall sense of well-being. The intervention was highly popular with subjects with the overwhelming majority enjoying the sit-stand station during work, with minimal disruption to workflow. Overall, a sit-stand desk may be a feasible approach towards reducing sedentary time at work, and increasing time spent in light activity, which may be a helpful approach in obesity and chronic disease prevention, along with healthy diet and exercise.

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Chapter 7 Appendix

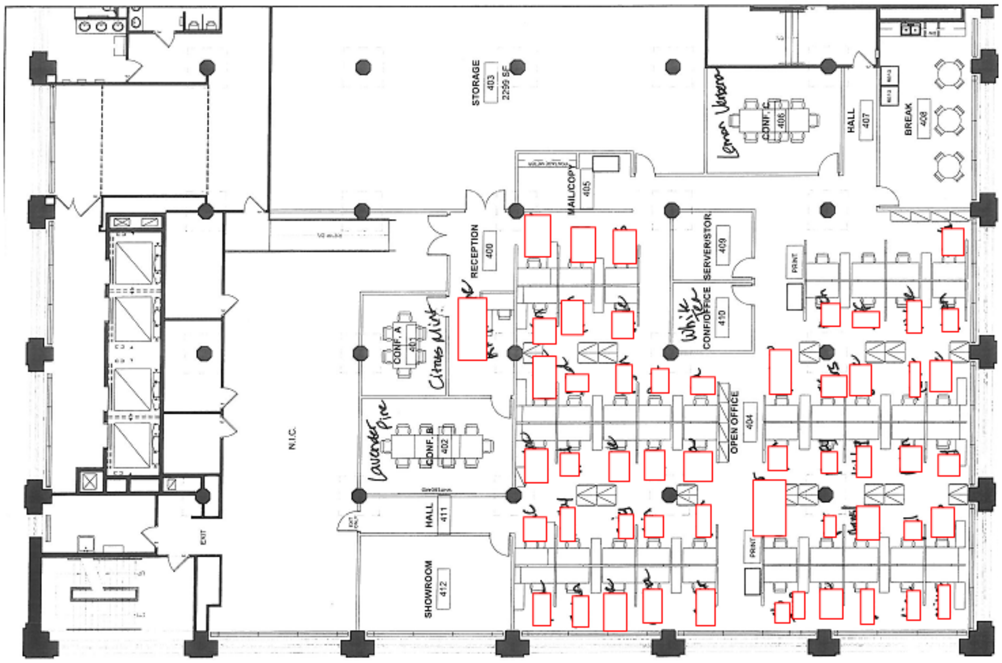

Figure 7-14th Floor Plan

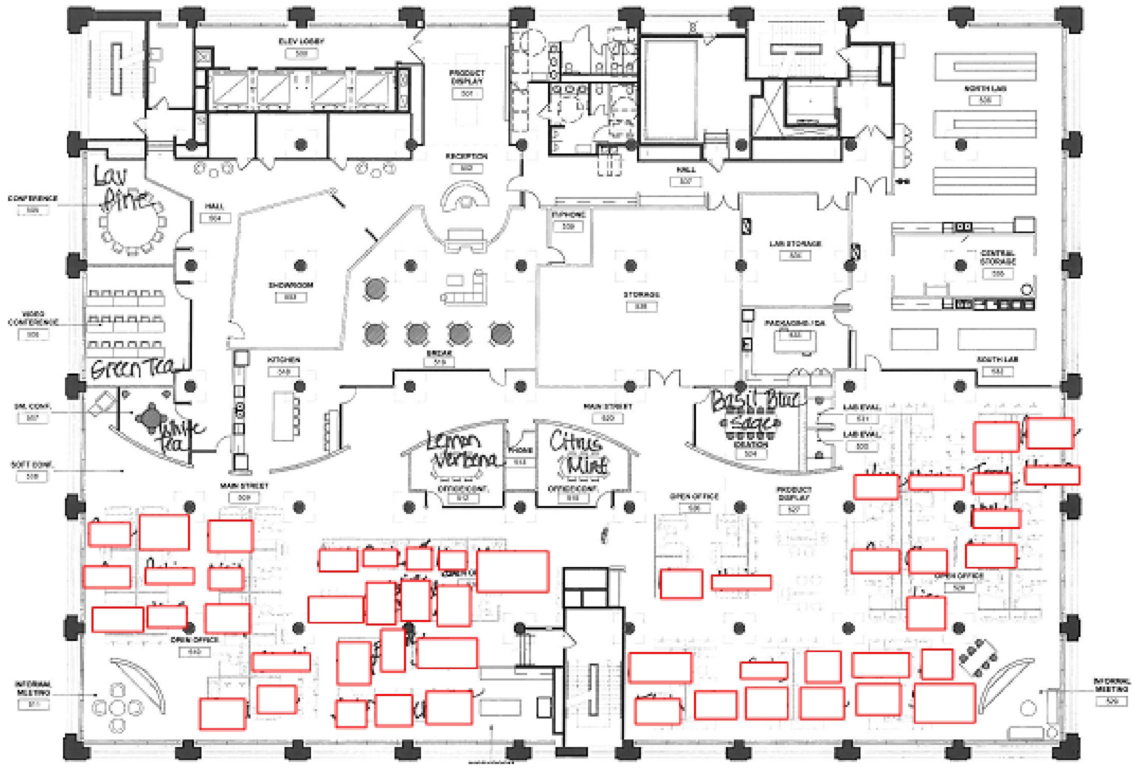

Figure 7-2 5th Floor plan

Sit-Stand Study Ecological Momentary Assessment

4. Are you currently sitting or standing?

- ○ Sitting
- ○ Standing

5. Please answer the following questions about how you feel right now. Base your responses on a scale of 1-5, where 1= not at all, and 5=extremely. The same response options will appear for each question.

	1. Not at all	2	3	4	5. Extremely
How HUNGRY are you right now?	○	○	○	○	○
How RELAXED are you right now?	○	○	○	○	○
How CALM are you right now?	○	○	○	○	○
How ENERGETIC are you right now?	○	○	○	○	○
How TIRED are you right now?	○	○	○	○	○
How SLUGGISH are you right now?	○	○	○	○	○
Overall, how WELL are you feeling right now?	○	○	○	○	○

Figure 7-3 Ecological Momentary Assessment.